

## **Report**

Groundwater Profiling Study  
Toms River Site

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# DRAFT

## TABLE OF CONTENTS

1.0	INTRODUCTION
2.0	RESULTS
3.0	CONCLUSIONS
4.0	TABLES
5.0	FIGURES
6.0	APPENDIX

## TABLES

TABLE 1	Summary of Profiling Work and VOC Analyses.
TABLE 2	Data Sheet for South Plume Yellow Clay
TABLE 3	Depth Averaged Concentrations for Layer 1 – South Plums
TABLE 4	Depth Averaged Concentrations for Layer 2 – South Plume
TABLE 5	Depth Averaged Concentrations for Layer 3 – South Plume
TABLE 6	Depth Averaged Concentrations for Layer 4 – South Plume
TABLE 7	All-inclusive Chemical Results
TABLE 8	All- inclusive Physico-Chemical Results

## FIGURES

Figure 1	Groundwater Profiling Locations and Transects – South Plume – Plan View
Figure 2	Transect A–A' Stratigraphy
Figure 3	Transect B–B' Stratigraphy
Figure 4	Transect C–C' Stratigraphy
Figure 5	Transect D–D' Stratigraphy
Figure 6	Transect E–E' Stratigraphy
Figure 7	Transect F–F' Stratigraphy
Figure 8	Transect G–G' Stratigraphy
Figure 9	Transect H–H' Stratigraphy
Figure 10	Transect I–I' Stratigraphy
Figure 11a	Transect A–A' - Trichloroethene

**FIGURES (Cont.)**

Figure11b	Transect B-B' - Trichloroethene
Figure11c	Transect C-C' - Trichloroethene
Figure11d	Transect D-D' - Trichloroethene
Figure11e	Transect E-E' - Trichloroethene
Figure11f	Transect F-F' - Trichloroethene
Figure11g	Transect G-G' - Trichloroethene
Figure11h	Transect H-H' - Trichloroethene
Figure11i	Transect I-I' - Trichloroethene
Figure12a	Transect A-A' - Tetrachloroethene
Figure12b	Transect B-B' - Tetrachloroethene
Figure12c	Transect C-C' - Tetrachloroethene
Figure12d	Transect D-D' - Tetrachloroethene
Figure12e	Transect E-E' - Tetrachloroethene
Figure12f	Transect F-F' - Tetrachloroethene
Figure12g	Transect G-G' - Tetrachloroethene
Figure12h	Transect H-H' - Tetrachloroethene
Figure12i	Transect I-I' - Tetrachloroethene
Figure13a	Transect A-A' - Chlorobenzene
Figure13b	Transect B-B' - Chlorobenzene
Figure13c	Transect C-C' - Chlorobenzene
Figure13d	Transect D-D' - Chlorobenzene
Figure13e	Transect E-E' - Chlorobenzene
Figure13f	Transect F-F' - Chlorobenzene
Figure13g	Transect G-G' - Chlorobenzene
Figure13h	Transect H-H' - Chlorobenzene
Figure13i	Transect I-I' - Chlorobenzene
Figure14a	Transect A-A' - 1,2-Dichlorobenzene
Figure14c	Transect C-C' - 1,2-Dichlorobenzene
Figure14e	Transect E-E' - 1,2-Dichlorobenzene
Figure15a	Transect A-A' - 1,2,4-Trichlorobenzene
Figure15b	Transect B-B' - 1,2,4-Trichlorobenzene
Figure15e	Transect E-E' - 1,2,4-Trichlorobenzene
Figure 16	Layers for Plan View, Depth Averaged Concentrations
Figure 17a	Layer 1 - Depth Averaged Trichloroethene Concentrations
Figure 17b	Layer 2 - Depth Averaged Trichloroethene Concentrations
Figure 17c	Layer 3 - Depth Averaged Trichloroethene Concentrations
Figure 17d	Layer 4 - Depth Averaged Trichloroethene Concentrations
Figure 18a	Layer 1 - Depth Averaged Tetrachloroethene Concentrations
Figure 18b	Layer 2 - Depth Averaged Tetrachloroethene Concentrations
Figure 18c	Layer 3 - Depth Averaged Tetrachloroethene Concentrations

## DRAFT

### FIGURES (Cont.)

Figure 18d	Layer 4 – Depth Averaged Tetrachloroethene Concentrations
Figure 19a	Layer 1 – Depth Averaged Chlorobenzene Concentrations
Figure 19b	Layer 2 – Depth Averaged Chlorobenzene Concentrations
Figure 19c	Layer 3 – Depth Averaged Chlorobenzene Concentrations
Figure 19d	Layer 4 – Depth Averaged Chlorobenzene Concentrations
Figure 20a	Layer 1 – Depth Averaged 1,2-Dichlorobenzene Concentrations
Figure 20b	Layer 2 – Depth Averaged 1,2-Dichlorobenzene Concentrations
Figure 20c	Layer 3 – Depth Averaged 1,2-Dichlorobenzene Concentrations
Figure 20d	Layer 4 – Depth Averaged 1,2-Dichlorobenzene Concentrations
Figure 21a	Layer 1 – Depth Averaged 1,2,4-Trichlorobenzene Concentrations
Figure 21b	Layer 2 – Depth Averaged 1,2,4-Trichlorobenzene Concentrations
Figure 21c	Layer 3 – Depth Averaged 1,2,4-Trichlorobenzene Concentrations
Figure 21d	Layer 4 – Depth Averaged 1,2,4-Trichlorobenzene Concentrations
Figure 22	Yellow Upper Clay Surface Contours – South Plume
Figure 23	Yellow Clay Isopachous Map – South Plume
Figure 24	South Plume – Hydraulic Head Distributions Transect D-D'
Figure 25	Groundwater Profiling Locations and Transects – North Plume
Figure 26	Transect J-J' Stratigraphy
Figure 27	Transect K-K' Stratigraphy
Figure 28	Transect L-L' Stratigraphy
Figure 29	Transect M-M' Stratigraphy
Figure 30a	Transect J-J' Chlorobenzene
Figure 30b	Transect K-K' Chlorobenzene
Figure 30c	Transect L-L' Chlorobenzene
Figure 30d	Transect M-M' Chlorobenzene
Figure 31a	Transect J-J' 2-Chlorotoluene
Figure 31b	Transect K-K' 2-Chlorotoluene
Figure 31c	Transect L-L' 2-Chlorotoluene
Figure 31d	Transect M-M' 2-Chlorotoluene
Figure 32a	Transect J-J' 1,2-Dichlorobenzene
Figure 32b	Transect K-K' 1,2-Dichlorobenzene
Figure 32c	Transect L-L' 1,2-Dichlorobenzene
Figure 32d	Transect L-L' 1,2-Dichlorobenzene
Figure 33a	Transect J-J' 1,2,4-Trichlorobenzene
Figure 33b	Transect K-K' 1,2,4-Trichlorobenzene
Figure 33c	Transect L-L' 1,2,4-Trichlorobenzene
Figure 33d	Transect L-L' 1,2,4-Trichlorobenzene

# DRAFT

## APPENDICES

Appendix      GC/MS Confirmation Study - Results and Related Figures

## **1.0 INTRODUCTION**

Ciba Specialty Chemicals (Ciba) contracted with Stone Environmental, Inc. (SEI) to perform a groundwater profiling study at the Toms River, New Jersey Site (site) beginning in May 1998 and continuing for nineteen field weeks between May 1998 and May 1999. Groundwater profiling is a relatively new technique that provides geochemical/geophysical data and groundwater samples at small depth intervals. The profiling work was part of the source area investigations that Ciba performed in support of the Feasibility Study for the Site. The Site has been the subject of extensive investigations prior to the profiling work and extensive reports have been written describing the Site, its history, physical features and the nature of the contamination problem there. This document is a summary of the data collected during the groundwater quality profiling project. This data summary is not a complete report on the Site and does not incorporate the extensive body of preexisting data. The reader is cautioned to avoid using this data alone in making interpretations regarding the nature of the groundwater plumes at the site. A report using all of the available data is included in Section 3 of the Feasibility Study (FS).

### **1.1 *Purpose and Objectives***

The overall purpose of this investigation is to support the CTM by verifying and/or refining the conceptual model for the transport of contaminant mass from the perched zone associated with certain source areas to the Primary Cohansey at the TRS. Specific objectives are:

1. Determine the vertical distribution of selected organic analytes in Primary Cohansey groundwater and in groundwater at selected locations in the perched zone.
2. Determine the vertical distribution of relative hydraulic conductivity in the perched zone and Primary Cohansey.
3. Determine, to the extent practicable, the mechanism(s) and their relative importance by which contaminants enter the Primary Cohansey from the zone above the Yellow Clay.
4. Identify; if practicable, discrete zones in the Primary Cohansey that contribute preferential transport of contaminants. (This is primarily a data interpretation exercise that includes (1) and (2) above.)

The uses of the data collected in this investigation include supplementing other data collected for interpreting conditions at the Site. Examples include 1) three dimensional delineation of the

## DRAFT

plumes, 2) supporting aspects of the CTM calibration effort such as supporting the location of mass injection points in the model and 3) verification/refinement of the conceptual model for the Site, such as to confirm the mechanisms responsible for transporting contaminants to the lower part of the Primary Cohansey.

### 1.2 Methods

All profiling was performed using Direct Push Technology and a modified version of the Waterloo Profiler. Work was performed under the supervision of a driller licensed in the State of New Jersey. When locations were completed they were staked and were subsequently surveyed. A total of 54 profiles, comprising a total of 3775 feet, were completed in the north and south plume areas of the Site (Table 1).

In general, the profiling was conducted in order to collect water samples from the Upper Cohansey (above the Yellow Clay Unit) and from the Primary Cohansey. In some locations no water was present above the Yellow Clay. Within the Primary Cohansey, samples were generally collected at a five-foot vertical spacing. A measure of relative permeability, known as the index of hydraulic conductivity ( $I_k$ ), was monitored in real-time while the profiler was advanced. When the  $I_k$  values indicated the presence of a low hydraulic conductivity layer, attempts were made to collect samples at the upper and lower interfaces of the low hydraulic conductivity unit.

Throughout the profiling work a field laboratory performed on-site VOC analysis of 550 groundwater samples (Table 1) using a gas chromatography technique. The results of this analytical method were calibrated against EPA method 8260. The target analytes included 18 volatile organic compounds ranging from light aliphatic compounds such as vinyl chloride to heavier aromatic compounds such as 1,2,4-trichlorobenzene. The work was completed in 19 weeks, which occurred over a 12-month period.

The types of data gathered during the course of this work, categorized as either chemical data or hydrogeological data are listed below.

1) Hydrogeological data acquired using Waterloo Profiler and  $I_k$  Tests:

- a) index of hydraulic conductivity ( $I_k$ );
- b) hydraulic head;

2) Chemical:

- a) VOC chemistry - 18 compounds, acquired using a field gas chromatograph;
- b) Field chemical data (acquired using YSI multi probe)- pH, specific conductance, dissolved oxygen, redox potential.

## DRAFT

All of the above data, with the exception of the  $I_k$  data, can be found in Tables 7 and 8 of this package.

### *1.2.1 Overview of Profiler*

A modified version of the Waterloo Profiler was used to obtain the groundwater profile data. The basis of the design of the profiler is to collect many closely spaced point samples in the vertical dimension, as well as to generate real time data that allows field decisions to be made regarding sampling depths. The Profiler can define solute distributions to an unusually high level of detail because very small volume samples are collected from a very narrow vertical interval at multiple depths in the same hole without withdrawing, decontaminating and re-driving the tool.

### *1.2.2 Profiler Components*

The Profiler, as originally designed at the University of Waterloo (Pitkin, 1994), was used to obtain water samples from unconsolidated porous media with hydraulic conductivities of  $10^{-4}$  cm/sec or higher. Recent modifications described by Pitkin (1998) have allowed the profiler to: 1) collect samples in lower hydraulic conductivity units; 2) resist plugging of the screens when passing through clayey zones; 3) measure hydraulic head; 4) measure hydraulic conductivity and; 5) measure physico-chemical properties such as pH, specific conductance, dissolved oxygen, oxidation/ reduction potential and temperature.

In the modified profiler used in this investigation, three tubes run from the ground surface to the profiler tip. Two of these tubes join at a small water reservoir. Two ball-type check valves are housed in the reservoir with two inlets (one from the surface, the other from the profiler ports) and an outlet (to the surface). A third tube runs from the ground surface to the profiler tip, bypassing the lower check valve. As the profiler is driven, de-ionized water is pushed down this tube and out the ports, keeping the ports clear and allowing for measurement of the index of hydraulic conductivity ( $I_k$ ).

Simultaneously, nitrogen is pushed through the sampling loop to purge it and to keep the de-ionized water from entering the sampling loop. When the profiler reaches the sample depth, the water is turned off and hydrostatic pressure forces water into the profiler and past the ball check valves. The inlet tube leading from the ground surface is connected to a controller box equipped with recharge and discharge timers and a pressure regulator. The control box times pulses of compressed nitrogen down the inlet tube. When a pulse of gas travels down the tube it forces the lower ball valve closed and the upper ball valve open and pushes the water in the tube up the outlet tube. The timer then shuts off the compressed gas pulse, the nitrogen in the system vents to atmospheric pressure, and hydrostatic pressure forces more water past the lower check



## DRAFT

valve into the tube. The upper check valve prevents the water in the discharge tube from draining back into the formation when the nitrogen pressure is released. The cycle is repeated until sufficient water has been purged from the formation and the sample is collected.

### *1.2.3 The Drive Platform*

The profiler was driven using a modified Mobile B57 drill rig on a Ford F800 truck. The rig has been modified with a Stanley Model MB356 hydraulic breaker hammer. This hammer provides 550 ft-lbs. per blow at 700 to 1200 blows per minute. The rig is capable of providing 18,650 pounds of down pressure and 28,270 pounds of retraction force. The rig is equipped with an 8,500-pound main hoist. This power is substantially greater than most direct push rigs both for advancing the tools into the ground and for retrieving them. In addition, if the terrain is so difficult that the direct push tools are refused even with the substantial power available, the rig is equipped with an auger head, which provides 8,500 ft-lbs. of torque. Using this auger head with 2¼ inch inside diameter hollow stem augers that accompany the rig allows for conventional auger drilling to depths of over 100 ft. The small diameter hollow stem augers can be used to overcome obstacles to driving the profiler and the profiler can then be inserted through the hollow stem augers and profiling can continue.

### *1.2.4 Data Acquisition*

Various sensors (see discussion below) are deployed during profiling and are wired to a signal conditioning device. The signal conditioning device outputs to a data acquisition board, which in turn outputs to a Pentium laptop computer. Data are processed and viewed graphically in real time on the laptop screen and the data are written to files on disk.

The following data were acquired in the field using the profiler:

#### 1) Collection of a water sample for analysis of target VOCs

At any desired depth, driving ceases and a sample is collected following the purging of an appropriate volume of water. An appropriate volume of water is defined as by equilibration of the field chemical parameters of the water as it is purged from the tip and lines.

#### 2) Rate of penetration

Rate of penetration was measured using a linear motion encoder mounted on the rig. This device electronically tracks the position of the hammer and therefore the depth of the profiler tip. The depth is divided by elapsed time to provide a rate of penetration log displayed in real time on a laptop computer.

## DRAFT

### 3) Index of hydraulic conductivity

The index of hydraulic conductivity is the flow rate of water pushed through the profiler into the formation using a compressed nitrogen pressure source divided by the corrected head (measured pressure - head loss due to friction). This value is not a hydraulic conductivity value but it provides an excellent indication of zones with relatively high versus low hydraulic conductivity, providing a useful tool for interpreting stratigraphy when calibrated against nearby soil boring(s). The flow and pressure are measured using an electronic pressure transducer and flow meter at the ground surface as water is pumped into the formation during driving. Data are logged on disk in the laptop and are plotted versus depth on the laptop screen in real time, as is the calculated index of hydraulic conductivity.

These data were used to determine the top and bottom of the Yellow Clay and the top of the Cohansey-Kirkwood Transition Unit. The data was also used to identify relatively high and low hydraulic conductivity zones within the Upper Cohansey and the Primary Cohansey and to target sampling to maximize the value of the data; e.g., selectively sample high conductivity zones or low conductivity zones.

### 4) Hydraulic head

Hydraulic head was measured by filling the profiler tube with analyte-free water and then suspending the column of water from a pressure transducer at the ground surface. The tension induced by the water column was converted to a length of water. This length is analogous to a depth to water measurement in a standard piezometer. Depth measurements were made relative to ground surface. Depth measurements were converted to an elevation from a common datum (MSL) following surveying of the profile locations to determine ground elevation.

### 5) Field chemical properties of groundwater

A series of water quality probes in a YSI Model 600XL sonde equipped with a custom built 50 ml volume flow cell was placed in-line on the discharge side of the pump. These probes monitored pH, specific conductance, temperature, dissolved oxygen and oxidation/reduction potential of water flowing past the flow cell. The values of these parameters were displayed versus time in graphical form on the laptop screen and were recorded on disk in the laptop. These data were used to determine when sufficient purging has occurred prior to sampling. The steady state data could be used to interpret the geochemical characteristics of the groundwater in the vicinity of the profile locations.

### 2.3.5 Field VOC analyses

The target VOCs in groundwater samples were analyzed on-site using a Solid Phase Micro extraction (SPME) sample preparation technique followed by analysis on a Hewlett Packard 5890 Series II Gas Chromatograph equipped with a Flame Ionization detector. The analyzed VOCs included vinyl chloride, 1,1,-dichloroethene, *trans*-1,2-dichloroethene, *cis*-1,2-dichloroethene, 1,1,1-trichloroethane, trichloroethene, 1,1,2-trichloroethane, perchloroethene, chlorobenzene, 1,2,3-trichloropropane, 2-chlorotoluene, 4-chlorotoluene, 1,3-, 1,2- and 1,4- dichlorobenzene, 1,2,4- and 1,2,3-trichlorobenzene. Detection limits were established during the method development work prior to the start of the field program and were less than 10 ppb for each of the target compounds. The analytical method was designed for very fast analytical run times of less than 10 minutes (including sample preparation). Run times were adjusted as necessary to elute the less volatile target analytes. All samples were analyzed using QA/QC protocols which are designed to follow EPA SW846 800 methodologies, the results are of the same quality as those of a conventional laboratory, which was confirmed by splitting selected samples with the Ciba Specialty Chemicals analytical laboratory on-Site, which used EPA method 8260.

## 2.0 Results

In this section, the major results of the investigation are discussed. There are two major types of results considered herein, 1) stratigraphy as defined using  $I_k$  data and 2) three-dimensional distribution of the target analytes. The discussion is organized by north and south plume, beginning with the south plume, the focus of the majority of the work.

### 2.1 South Plume Results

#### 2.1.1. Stratigraphy

The index of hydraulic conductivity ( $I_k$ ) data were used to infer the positions of the units acting as aquitards at the site, particularly the Yellow Clay and the Cohansey-Kirkwood Transition Unit. Plots of the index of hydraulic conductivity in cross sections are shown on Figures 2 through 10. In interpreting  $I_k$  data, the top boundary of a less permeable unit/layer is indicated by a visible drop in the  $I_k$  value versus depth, while the opposite is true for the bottom boundary of the unit/layer. The Yellow Clay Unit was defined in two ways during our assessment of the profiling data. In the first approach we defined the unit as the "Massive Yellow Clay" and in the second approach we defined the unit as the "Interbedded Yellow Clay". The Massive Yellow Clay is part of the Interbedded Yellow Clay, and it is characterized by continuously low  $I_k$  values. Table 2 presents the top and bottom elevations of the respective units as well as the

## DRAFT

thickness of the interbedded unit. The Yellow Clay as discussed herein and as presented in the Figures is the Interbedded Yellow Clay, which is actually a series of clay layers which are interbedded with sand. The interbedding is apparent on plots of  $I_k$  versus depth because the values shift between low and high and back again over short depth changes (inches).

The upper surface of the Yellow Clay is highest in the southwest section of this study area, beneath the LSD and southeast portion of the DDA, and slopes in an easterly direction with a northward component (ENE) as shown on Figure 22. The upper surface of the Yellow Clay drops from approximately 34 feet above mean sea level at the southeastern corner of the DDA to approximately 4 feet at DPT SE17, a distance of approximately 2000 feet.

The thickness of the Yellow Clay is greatest near DPTSE30 where it is approximately 15 feet thick (Figure 23). This also corresponds to the location where the top of the clay surface is at the highest elevation. There appears to be a zone of relatively thick clay (>10 ft.) running west to east from the LSD to the northern portion of the FCD. The clay thins in all directions away from this thick "core", notably pinching out in the north. .

The upper surface of the Cohansey-Kirkwood Transition Unit is generally found at elevations between -20 and -30 feet relative to mean sea level, where it was encountered. The nature of the contact between the Primary Cohansey and the Cohansey-Kirkwood Transition Unit was generally gradational, with interfingering

observed in several cases, based on examination of  $I_k$  versus depth profiles. On occasion, the contact between the two intervals was difficult to interpret based on  $I_k$  data.

Inferred stratigraphy interpretations in cross-section are included on Figures 2 through 10. Two of the three longitudinal cross-sections (longitudinal refers to downdip (Figure 9 and Figure 10) show two important features of the Yellow Clay; 1) its tendency to dip in a southeasterly direction with a slope on the order of 0.01 and 2) its continuity over greater than 1,800 feet in that direction from the DDA. The other longitudinal transect, Figure 8, shows how the Yellow Clay pinches out between profile locations DPTSE21 and DPTSE10, in the northern portion of the south plume study area. A third, important feature of the Yellow Clay is illustrated in Figure 2. Thin, locally correlated higher permeability zones (sand lenses) are observed within the Yellow Clay. Such sand lenses are also correlated longitudinally (Figure 9 and Figure 10). Correlation distances for individual sand lenses appear to be as long as several hundred feet in the transverse direction and as long as 1,000 feet in the longitudinal direction.

Other, locally correlated zones of lower permeability have also been observed in the profile data. Such zones have been observed above the Yellow Clay (Figure 6 (*Transect E-E'*)) and below the Yellow Clay (Figure 2). Correlation distances for these lower permeable units (silt or

## DRAFT

clay) are up to several hundred feet (600 to 800 ft.).

### 2.1.2. *Contaminant Distributions*

This section describes major features of contaminant distributions in the south plume as interpreted from the profiling data only. Because the scope of the groundwater profiling work was limited in purpose and area, a full interpretation of the plume must make use of all the available data, most notably that obtained from the substantial local monitoring well network. This will be included in the Feasibility Study Report.

The usefulness of the profiling data is reflected in a better understanding of the vertical distribution of the contaminants within the south plume, especially as this distribution relates to stratigraphy. This discussion of the results focuses on this topic.

The profiling work included the analysis of (18) compounds. In the south plume, the contaminants most commonly found with the highest concentrations were chlorobenzene; 1,2-dichlorobenzene, tetrachloroethene and trichloroethene. In general and with few exceptions, the distributions of the different analytes tend to be similar.

Relatively high concentrations of the analytes were associated with important stratigraphic features. For the purpose of this discussion, consider the distribution of concentrations of 1 mg/L or more of at least one target analyte. The selection of 1 mg/L or higher concentrations for this discussion is rather arbitrary. The results described below would also apply, in kind, to an analysis of the distribution of concentrations of 100 µg/L or more. This was not done because the higher concentrations are sufficient to make the points that are made in this discussion.

In the south plume, concentrations of at least one analyte exceeded 1 mg/L in 21 profile locations. Sixteen (16) of those locations had hits of greater than 1 mg/L associated with the Yellow Clay. There were three ways in which such samples were associated with the Yellow Clay, 1) samples at or near the top of the clay, 2) samples at the bottom or just below the clay or 3) samples located in sand stringers interbedded with the Yellow Clay. High concentrations could be associated with the clay matrix itself, but the tightness of the unit precludes obtaining suitable groundwater samples. In the profile data, four (4) locations above the clay (Figures 13e, 13f, 14a, 14h, and 13l), eight (8) locations at or near the bottom of the clay (Figures 11b, 13f, 14a, 14g, 14h, and 13l) and four (4) locations within sand stringers in the interfingered clay (Figures 11a, 12B, 14a, 15a, 15b, 13h, 14h and 15h) were observed. A major implication of this data is that relatively high concentrations of dissolved contaminants have migrated through the clay and into the top of the Primary Cohansey.

Three (3) locations (Figures 13d, 13f and 13g) with concentrations of at least one target analyte above 1 mg/L located at the top of the Cohansey-Kirkwood Transition Unit were noted. A

## DRAFT

possible fourth location is the demonstration profile location, 744-12, but  $I_k$  data was not collected in this profile to verify that the unit was reached.

Five (5) locations with detections greater than 1 mg/L were observed within the Primary Cohansey, but not associated with either the Yellow Clay or the Cohansey-Kirkwood Transition Unit (Figures 11a, 13f, 14g, 13l). At least two of these were associated with minor, low permeability lenses. Two of the locations, DPTSE16 and DPTSE17, are located downgradient from the FCD. The relatively broad distribution of high concentrations across the Primary Cohansey at these latter two locations can be largely attributed to the effect of nearby pumping.

Besides the strong correlation between the distribution of the major target analytes and stratigraphy, another interesting observation is that most of the greater than 1 mg/L locations involve chlorobenzene as one of the analytes present at those concentrations. This suggests that chlorobenzene is a suitable surrogate for the distribution of high concentrations of target analytes in the south plume. Only two greater than 1 mg/L locations did not include chlorobenzene among the major analytes, DPTSE30 and DPTSE37. Both of these locations are within the footprint of the DDA and source heterogeneity can explain the absence of high concentrations of chlorobenzene in these locations.

Samples with four (4) or more analytes exceeding 1 mg/L each are also associated with locations proximal to sources. Five (5) such locations were identified in the south plume, DPTSE20, DPTSE21, DPTSE23, DPTSE26 and DPTSE28. These locations, except for DPTSE 20 and DPTSE28, are located within the footprint of the DDA. However, four (4) of the samples, including those two outside of the DDA footprint, lie within a locally correlated, thin sand layer within the Yellow Clay. This observation explains how such high concentrations migrated to DPTSE20 and DPTSE28 from the DDA.

Figures 17 through 21 provide a sense of the three-dimensional distribution of the major target analytes in the south plume study area. The data used in preparing these figures are summarized on Tables 3 through 6. Each figure presents a depth-averaged contour map of a single analyte located in one of four (4) layers. Figure 16 defines the layers used in these figures. Layer 1 represents the Upper Cohansey, including the entire Yellow Clay. The other three layers represent the top, middle and bottom of the Primary Cohansey, respectively.

In layer 1, the topmost layer, the analytes are distributed similarly and the highest concentrations are associated with the two major south plume source areas, the DDA/SPB and the FCD/TDA. The high concentrations in DPTSE28, located near the middle of the LSD, as discussed before, is located within a sand lense in the Yellow Clay that correlates locally with a sand lense in the DDA, explaining how high concentrations have migrated to the south of the DDA. In both source area vicinities, the highest concentration analyte is chlorobenzene.

In general, the depth averaged concentrations in Layer 2, the top of the Primary Cohansey, are

## DRAFT

lower than for Layer 1, i.e., maximum depth-averaged concentrations are lower and the highest concentration contour in Layer 1 has disappeared from Layer 2 in every case except for 1,2-DCB. Also, relative to Layer 1, the high concentration contours for each analyte is shifted to the east or southeast, indicative of downward and downgradient migration of dissolved mass from the source areas.

Similar changes are also generally the rule when comparing Layer 3 with Layer 2. The only notable exception is the higher depth averaged concentration in DPTSE37 (1,610 µg/L), attributed to a single sample. This location is beneath the footprint of the DDA.

A comparison of Layer 4 with Layer 3 is not quite as simple as the previous comparisons. Although the peak depth-averaged concentration of TCE has dropped between the two layers (Figure 17d and Figure 17c), a thin zone of 100 µg/L or higher concentrations lies from the northwest corner of the study area to the east, indicating a downward and downgradient spread of TCE. This likely represents downward and downgradient migration of dissolved TCE from the vicinity of DPTSE37. Tetrachloroethene concentrations behave more as is expected, i.e., the concentrations are lower in Layer 4 and the higher concentrations have shifted more to the east relative to layer 3. Chlorobenzene peak concentrations have shifted to the east relative to the DDA, as expected, but the peak, depth-averaged concentrations appear to be locally higher than for Layer 3 (Figure 19c and Figure 19d). The distribution of the greater than 1 mg/L concentrations in Layer 4 are consistent with downward and downgradient migration of dissolved chlorobenzene from the DDA. The situation with 1,2-DCB is similar to that for chlorobenzene. Trichlorobenzene also apparently shows downward and downgradient migration (Figure 21c and Figure 21d), possibly from the vicinity of DPTSE11 in Layer 3, also consistent with migration of dissolved contamination from the DDA. Thus, a detailed comparison of the depth-averaged concentration data between Layer 3 and Layer 4 indicates dissolved transport of contaminants from the DDA over most of the study area, with similar transport from the FCD/TDA.

### 2.1.3 Field Analytical Parameters

Field analytical parameters are included in Table 8. The primary reason for measuring field parameters in the profiling project was to determine when sufficient water had been purged from the profiler to collect a representative sample of formation water. To this end, parameters were measured during purging of the profiler lines until readings reached a near steady state. The final steady state data does say something regarding the geochemical characteristics of the groundwater, however.

Dissolved oxygen (D.O.) and oxidation-reduction potential (Eh) data in the south plume indicated the presence of groundwater ranging from aerobic to anoxic. Strongly anoxic conditions are produced by microbial activity, which uses up available oxygen, in areas with relatively high dissolved organics, which include the contaminants. The dissolved oxygen and

## DRAFT

Eh data were consistent with each other, as expected, i.e.; low Eh values generally corresponded to low D.O. values. Values for pH in DPT probe locations were consistent with those values collected in monitor wells in the south plume. In general, the values ranged between 5 and 7.5 S.U. The high pH reading of 9.77 at the top of profile DPTSE28 can be attributed to that sample location being located near the waste residue in the LSD. DPTSE 27 is also located in the LSD, which can explain the relatively high pH values in that profile. The influence of the LSD may also account for the relatively high value of 8.22 at the top of the profile, DPTSE34, or the middle sample in DPTSE20, which are located proximal to and downgradient of the LSD.

Specific conductance is a measure of the ability of the water to conduct an electrical current, which is positively related to the total dissolved solids content of the water. Relatively high values of specific conductance ( $>1,000 \mu\text{S}/\text{cm}$  for the Site) are related to the presence of relatively high concentrations of contaminants, but are also related to the presence of clay layers or areas with relatively high natural salinity. The specific conductance data on Table 8, when compared to the stratigraphy and the concentrations of target analytes, are consistent with these expectations.

### 2.1.4 Hydrology

Depth-to-water measurements were made using the profiler at most sample locations using the approach described in Section 1.2.4. Where the depth to water was in the vicinity of or deeper than the suction limit (approximately 27 ft.), the approach used was not reliable and, on occasion, when the profiler was in a low hydraulic conductivity unit, the time required for the water level to equilibrate was excessive, a measurement was not recorded. Hydraulic heads were calculated by subtracting the depth to water from the ground surface elevation. These head measurements were collected over a twelve-month period so a site wide interpretation of flow patterns from these data is tenuous. The data are most useful in assessing the vertical components of the hydraulic gradient at each profiling location.

Considering the caveat that the hydraulic data have been collected over a period of several months, two general statements can be made from review of the data, as illustrated in Figure 24. In general, there is a strong downward vertical gradient across the Yellow Clay to the Primary Cohansey. Within the Primary Cohansey, the hydraulic gradient is nearly horizontal, indicating generally horizontal flow. Even with generally horizontal flow, there is a smaller vertical component of flow within the Primary Cohansey, which is readily observed in monitor well clusters where hydraulic head readings are taken at the same time. The DPT data are not appropriate for determining the degree of this vertical component of flow in the Primary Cohansey across wide areas of the plume, given the relatively long time interval over which the data was collected. In interpreting groundwater flow directions, data collected from groundwater monitoring wells and piezometers should be considered.



## 2.2 North Plume Results

The objectives of the profiling work in the north plume were; 1) determine the vertical distribution of target analytes in the north plume, especially as it may relate to stratigraphy, and 2) in a transverse cross-section, determine the anatomy of the plume near and downgradient of the major, upgradient source areas, the FSD, UST/108 and EQ. To meet these objectives, the amount of groundwater profiling data obtained in the north plume was small relative to the south plume. Because degree of characterization achieved during profiling of the north plume was less, the discussion of the results is less detailed than for the south plume.

### 2.2.1. Stratigraphy

The locations of the transects in the north plume are indicated on Figure 25. In general, the stratigraphy is consistent with that described in previous investigations. As is apparent from the stratigraphic cross-sections (Figure 26, Figure 27, Figure 28 and Figure 29), additional, thin units of locally correlated low permeability (silty units) were observed in the  $I_k$  data. These fine units correlated over distances from 50 to greater than 800 ft. In the vicinity of the Former South Dye area (FSD), the Yellow Clay consists of interbedded clay, silt and sand and is typically greater than 10 ft. thick (Figure 26). Although individual sand stringers in the clay can be correlated over distances of 100 or more feet, most of those in the clay could not. Previous investigations, such as the NAPL Action Plan Investigation, have shown that the clay is not continuous between transects J-J' and K-K'. Across transect K-K', to the east, the clay is thinner (Figure 27).

In the north plume, the contact between the Primary Cohansey and the Cohansey-Kirkwood Transition Unit is characterized by interfingering of sandy and silty lenses, with a gradational contact occasionally observed, such as at location PRO8. The location of the contact between the two units is consistent with previous studies at the Site.

### 2.2.2 Contaminant Distributions

The contaminant distribution in the north plume can be correlated with stratigraphy, just as it was in the south plume. In cross-section J-J' (Figures 30a, 31a, 32a and 33b), two zones of high concentrations of target analytes are indicated. An upper zone is associated with the perched groundwater zone and the Yellow Clay. The degree of interbedding between clay and sandy/silty intervals is high, so no attempts were made to correlate the concentrations with individual beds of relative high or low permeability within the Yellow Clay unit. The lower zone of high concentrations lies below a lower silt layer that was correlated across the cross-section and above the Cohansey-Kirkwood Transition unit. This silt layer lies across the 0 ft. MSL elevation interval. The contamination zone (2-chlorotoluene and 1,2-dichlorobenzene) pinches out about halfway across the cross-section to the south, near DPTPRO10. The northern limit of either zone was not determined in this investigation.

## DRAFT

Along Transect K-K', three features of the distribution of target analytes become apparent upon examination of the data, 1) all significant concentrations occur below the 20 ft. MSL elevation in the Primary Cohansey, 2) there is no obvious correlation between high concentrations of the target analytes and stratigraphy, and 3) the distribution of each of the four target analytes in the cross-sections is different. Chlorobenzene and 1,2-dichlorobenzene are distributed in two similar zones, one that crosses DPTPRO03 and DPTPRO02 to the north and a second zone across much of the lower portion of the Primary Cohansey in the vicinity of DPTPRO05, which lies adjacent to the northeast corner of the EQ. 2-Chlorotoluene concentrations are high (>1mg/L) throughout the lower portion of the Primary Cohansey in DPTPRO03, while mg/L levels of 1,2,4-trichlorobenzene are similarly distributed vertically, but are centered in the vicinity of DPTPRO08, several hundred feet to the south. Relatively high concentrations (>1 mg/L) of 2-chlorotoluene, 1,2-dichlorobenzene and 1,2,4-trichlorobenzene occur in W216, the southernmost point of the cross-section and downgradient from the southeast corner of the EQ. These observations suggest that there are several different sources of these compounds in the north plume. Source areas in this upgradient part of the north plume are the EQ, the FSD, and the UST/108.

In the longitudinal transects, L-L' and M-M', it is again observed that most of the >1 mg/L concentrations occur below 20 ft. MSL in elevation, except in the vicinity of the FSD, as seen in DPTPRO010 in those cross-sections and in cross-section J-J'. Mg/L concentrations of 2-chlorotoluene and 1,2,4-trichlorobenzene were observed on top of and into the Cohansey-Kirkwood Transition Unit in DPTPRO06. Only 2-chlorotoluene was observed on top of the transition unit in DPTPRO10, located upgradient from DPTPRO06 and in the FSD. Transect M-M' shows >1 mg/L concentrations of 2-chlorotoluene and chlorobenzene persisting across the entire transect, a distance of over 1200 feet. Groundwater flow is generally along this transect, so it is roughly parallel to the plume axis.

### 2.2.3 Field Analytical Parameters

The general discussion in subsection 2.1.3 regarding the field analytical parameters also applies to the north plume. An example of the relationship between contaminant levels (Table 7) and D.O. and Eh data (Table 8) is DPTPRO06, located between the FSD and former building 108. In this profile, target analyte concentrations in the topmost three samples were in the 10's of µg/L range, D.O. concentrations were greater than 2.5 mg/L and Eh values were greater than 75. In the bottom six (6) samples, target analyte concentrations of a few compounds were generally in the mg/L range, with D.O. levels below 1 mg/L and typically negative Eh values indicative of reducing conditions.

In the north plume, specific conductance levels were always below 1,000 µS/cm, and typically below 500 µS/cm, except for points below -30 ft. MSL in profiles DPTW209, DPTW210 and DPTW310, which were located adjacent to GERS pumping wells. These deep points are in the

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Lower Cohansey. No other profile locations in the north plume penetrated the Lower Cohansey. Concentrations of target analytes at these locations typically were on the order of mg/L for at least one compound in the Lower Cohansey at these profile locations. In the profiles in the Primary Cohansey in the north plume, there did not appear to be as clear a relationship between specific conductance and target analyte concentrations.

### **3.0 CONCLUSIONS**

The groundwater profiling work provided insight into the vertical distribution of contaminants in the north and south plume of the Site. In the south plume, relatively high concentrations were associated with stratigraphic features such as the Yellow Clay and the top of the Cohansey-Kirkwood Transition Unit. Also, preferential flow or migration pathways for dissolved contaminants appear to occur in locally correlated sand units within the Cohansey Yellow Clay. This is especially apparent in the case where higher concentrations of target analytes were observed in a sand lense within the Yellow Clay below the LSD. This occurrence most likely resulted from the transport of dissolved contaminants from beneath the DDA in the same locally correlated sand lense. The distribution of target analytes in the south plume is consistent with the downward and dowgradient migration of contaminants from known source areas, particularly the DDA/SPB and FCD/TDA areas.

In general, while the target analyte distribution based on north plume groundwater profile data is consistent with the migration of dissolved constituents from known source areas, particularly the former EQ Basins, the FSD and the UST/108 areas along the known direction of groundwater flow, it is not obvious. A more detailed evaluation of the contaminant distribution in the north plume, as well as the south plume, using all available data collected over the past two years, is presented in Section 3.2 of the Feasibility Study (FS). The relationship between major stratigraphic features and the distribution of target analytes is not as strong as it was for the south plume.

A characterization of Site groundwater quality using all available data collected over the previous two years is found in Section 3.2 of the FS. Monitoring well data obtained from the SWMP, the Intrinsic Bioremediation Demonstration Study and the Supplemental Groundwater Investigation were used to characterize the plumes at the Site in the FS, as well as groundwater profile data.

Groundwater profile data will be used to aid optimization of the GERS. For GERS optimization, the profile data provides details on the vertical distribution of contaminants not found in monitor wells. For example, this will help to appropriately select screened intervals for pumping, based on relative concentrations.

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## 4.0 TABLES

## 5.0 FIGURES

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**6.0 APPENDIX – GC/MC CONFIRMATION STUDY**